INTERNATIONAL STANDARD

ISO 16063-45

First edition
2017-05

Methods for the calibration of vibration and shock transducers —

Part 45:
In-situ calibration of transducers with built in calibration coil

Méthodes pour l'étalonnage des transducteurs de vibrations et de chocs —

Partie 45: Partie 45: Étalonnage sur site des transducteurs munis d'une bobine d'étalonnage intégrée

Reference number
ISO 16063-45:2017(E)

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

A list of all parts in the ISO 16063 series can be found on the ISO website.

Methods for the calibration of vibration and shock transducers —

Part 45: In-situ calibration of transducers with built in calibration coil

1 Scope

This document specifies the calibration of vibration transducers with built-in calibration coils in laboratory and in situ. In laboratory, the method described can be applied to calibrate the vibration sensitivity and electrical sensitivity, and to obtain the coefficient of calibration coil. In situ, it can be used to calibrate the electrical sensitivity and vibration sensitivity using electrical instrumentation.

This document specifies the instrumentation and procedure for performing calibrations of vibration transducers with built-in calibration coils in the frequency range typically from 0,1 Hz to 100 Hz.

The expanded uncertainty can be evaluated using the method given in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16063-1, *Methods for the calibration of vibration and shock transducers — Part 1: Basic concepts*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at www.iso.org/obp

— IEC Electropedia: available at www.electropedia.org

3.1
vibration transducer with built-in calibration coils
vibration transducer employing calibration coils as internal exciting elements for which seismic mass is excited to vibrate by electromagnetic force produced by the exciting electrical signal of the calibration coil

EXAMPLE 1 Pendulum.

EXAMPLE 2 Seismometers and electromagnetic transducers with built-in calibration coils.

3.2
electrical sensitivity
<for vibration transducer with built-in calibration coils> ratio of the electrical output of the vibration transducer to the exciting electrical signal of the calibration coil in the absence of mechanical excitation parallel to a specified axis of *sensitivity* (3.3) at the mounting surface

3.3
sensitivity
<for linear transducer> ratio of the transducer electrical output to its mechanical input during sinusoidal excitation applied parallel to a specified axis of sensitivity at the mounting surface

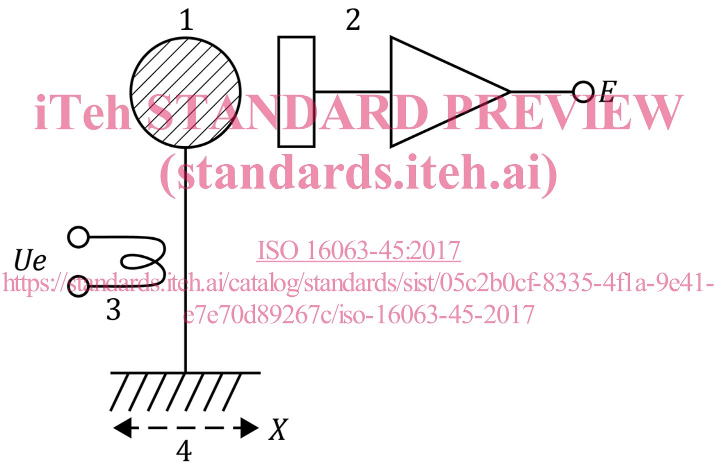
3.4
coefficient of calibration coil
<for vibration transducer with built-in calibration coils> ratio of the *electrical sensitivity* (3.2) to *sensitivity* (3.3)

Note 1 to entry: The coefficient of calibration coil is frequency dependent.

4 Calibration

4.1 General

The principle of a vibration transducer with built-in calibration coils is illustrated in Figure 1. The pendulum vibrates under the inertia force produced by measured vibration. A calibration coil can be used to produce the equivalent electromagnetic force to simulate the inertial force required to vibrate the pendulum.

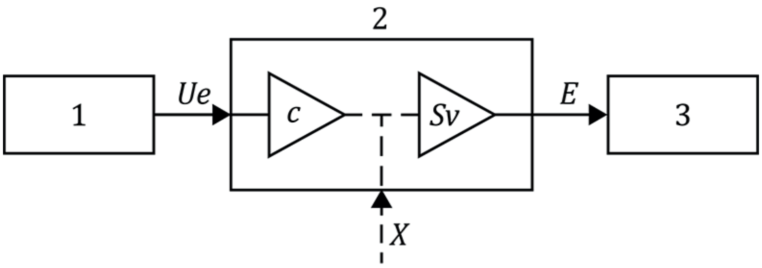


Key

1	pendulum	*Ue*	exciting electrical signal of the calibration coil
2	sensing element	*E*	output electrical signal of the transducer
3	calibration coil	*X*	vibration measured by the transducer
4	measured vibration		

Figure 1 — Principle of a vibration transducer with built-in calibration coils

The signals and instrumentations used in the calibration of vibration transducers with built-in calibration coils are shown in Figure 2.



Key

1	frequency generator and indicator	*c*	coefficient of calibration coil
2	vibration transducer with built-in calibration coils	*Sv*	sensitivity
3	voltage measuring instrumentation	*E*	output electrical signal of the transducer
Ue	exciting electrical signal of the calibration coil	*X*	vibration measured by the transducer

Figure 2 — Measuring system for calibration of a vibration transducer with built-in calibration coils

The electrical sensitivity of the vibration transducer with built-in calibration coils is given in Formula (1):

$$S = \frac{E}{Ue} \tag{1}$$

The sensitivity of the vibration transducer with built-in calibration coil is given in Formula (2):

$$Sv = \frac{E}{X} \tag{2}$$

The coefficient of calibration coil is given in Formula (3):

$$c = \frac{S}{Sv} \tag{3}$$

According to Formula (1) to Formula (3), the electric sensitivity of the vibration transducer with built-in calibration coil can described as given in Formula (4):

$$S = cSv \tag{4}$$

NOTE Further information on the application of calibration coils is given in Annex C.

4.2 Calibration procedure

4.2.1 General

Calibration of vibration transducers with built-in calibration coils comprises two parts: calibration in laboratory and in-situ calibration.

Before the transducers are employed in situ, calibration can be made in laboratory: the sensitivity can be calibrated by primary or comparison methods; the electrical sensitivity can be calibrated by the frequency generator and indicator and voltage measuring instrumentation; and the coefficient of calibration coil can be calculated according to Formula (3).

After the transducers are employed in situ, the electrical sensitivity can be calibrated by the frequency generator and indicator and voltage measuring instrumentation and the sensitivity can be calculated according to Formula (4) using the coefficient of calibration coil obtained in laboratory.

4.2.2 Calibration in laboratory

4.2.2.1 Calibration of the sensitivity

Determine the sensitivity at the reference frequency (f_{ref}) and acceleration (X_{ref}) using primary or comparison methods. The amplitude of output electrical signal of the transducer is E_{ref} .

$$Sv_{ref} = \frac{E_{ref}}{X_{ref}}$$

Then, determine the sensitivities at other calibration frequencies and accelerations using primary or comparison methods.

4.2.2.2 Calibration of the electrical sensitivity

At the reference frequency (f_{ref}), adjust the exciting electrical signal of the calibration coil so that the amplitude of output electrical signal of the transducer equals E_{ref} . The amplitude of exciting electrical signal (Ue_{ref}) is being measured simultaneously. The electrical sensitivity at the reference point is given as follows:

$$S_{ref} = \frac{E_{ref}}{Ue_{ref}}$$

Then, determine the electrical sensitivities at other calibration points using the frequency generator and indicator and voltage measuring instrumentation.

4.2.2.3 Calibration of the coefficient of calibration coil

The coefficient of calibration coil at the reference point is calculated according to Formula (3):

$$c_{ref} = \frac{S_{ref}}{Sv_{ref}}$$

Then, calculate the coefficient of calibration coil at other calibration points.

4.2.3 In-situ calibration

4.2.3.1 In-situ calibration of the electrical sensitivity

At the reference frequency (f_{ref}), adjust the exciting electrical signal of the calibration coil so that the amplitude of output electrical signal of the transducer equals E_{ref}. The amplitude of exciting electrical signal (Ue_{2ref}) is being measured simultaneously. The electrical sensitivity at the reference point is given as follows:

$$S_{2ref} = \frac{E_{ref}}{Ue_{2ref}}$$

Then, determine the electrical sensitivities at other calibration points using the frequency generator and indicator and voltage measuring instrumentation.

4.2.3.2 In-situ calibration of the sensitivity

At the reference point, according to Formula (4), the sensitivity is calculated using the coefficient of calibration coil calibrated in laboratory.

$$Sv_{2\text{ref}} = \frac{S_{2\text{ref}}}{c_{\text{ref}}}$$

Then, calculate the sensitivities at other calibration points.

4.3 Preferred amplitudes and frequencies

The frequencies, each with associated accelerations, velocities or displacements (amplitude or r.m.s. value) equally covering the transducer range, should preferably be chosen from the following series.

a) Accelerations (m/s^2), velocities (m/s) and displacements (mm):

Magnitude values should be selected in 1 – 2 – 5 steps, e.g. 0,01; 0,02; 0,05; 0,1; 0,2; 0,5; 1; 2; 5; 10 ...

NOTE The selected amplitudes depend on the measurement type and range of the transducer calibrated.

b) Frequency (Hz):

Selected from the standardized one-third-octave-frequency series (see ISO 266) between 0,1 Hz and 100 Hz (or the series of radian frequencies evolving from ω = 1 000 rad/s).

5 Uncertainty of measurements

5.1 All users of this document shall make uncertainty budgets in accordance with Annex A to document their level of uncertainty. An example is given in Annex B.

To help set up systems fulfilling different requirements and environmental conditions, two examples are given in a) and b) below. For each, system requirements are set up and the attainable uncertainty is given. These two examples are used throughout this document.

a) Example 1

The sensitivity is calibrated by primary means and documented uncertainty. In the primary vibration calibration laboratory, the electrical sensitivity and coefficient of calibration coil are measured. In situ (for example, cave with seismometers), the electrical sensitivity and sensitivity are measured. The environmental conditions are well controlled within the limits given in Table 1. The electrical instrumentations fulfil the requirements given in Table 2 and Table 3.

Table 1 — Environmental conditions for Example 1

Site	Parameter	Limit
Vibration calibration laboratory	Temperature	(23 ± 3) °C
	Relative humidity	75 % max.
	Environmental vibration	VC-E (3 µm/s)
In situ	Temperature	(23 ± 10) °C
	Relative humidity	75 % max.
	Environmental vibration	VC-E (3 µm/s)
NOTE VC-E is described in ISO/TS 10811-2:2000, Clause 7.		

Table 2 — Frequency generators and indicators for Example 1

Parameter	Unit	Limit
Frequency uncertainty	%	0,05 %
Frequency stability	% of reading over the measurement period	0,05 %
Amplitude stability	% of reading over the measurement period	0,05 %

Table 3 — Voltage measuring instrumentation for Example 1

Parameter	Unit	Limit
Frequency range	Hz	0,1 Hz~100 Hz
Relative expanded uncertainty of voltage	%	0,2

b) Example 2

The sensitivity is calibrated by comparison means and documented uncertainty. In the comparison vibration calibration laboratory, the electrical sensitivity and coefficient of calibration coil are measured. In situ (for example, bridges furnished with electromagnetic transducers), the electrical sensitivity and sensitivity are measured. The environmental conditions are such that only less narrow tolerances can be maintained, as per the limits given in Table 4. The electrical instrumentations fulfil the requirements given in Table 5 and Table 6.

Table 4 — Environmental conditions for Example 2

Site	Parameter	Limit
Vibration calibration laboratory	Temperature	(23 ± 5) °C
	Relative humidity	75 % max.
	Environmental vibration	VC-D (6 μm/s)
In situ	Temperature	(−40~60) °C
	Relative humidity	90 % max.
	Environmental vibration	VC-B (25 μm/s)
NOTE VC-D and VC-B are described in ISO/TS 10811-2:2000, Clause 7.		

Table 5 — Frequency generators and indicators for Example 2

Parameter	Unit	Limit
Frequency uncertainty	%	0,1 %
Frequency stability	% of reading over the measurement period	0,1 %
Amplitude stability	% of reading over the measurement period	0,1 %

Table 6 — Voltage measuring instrumentation for Example 2

Parameter	Unit	Limit
Frequency range	Hz	0,1 Hz~100 Hz
Relative expanded uncertainty of voltage	%	0,4

5.2 Attainable uncertainties are expanded uncertainties calculated using a coverage factor of 2 in accordance with ISO 16063-1. Two examples are given in Table 7. In practice, these limits may be exceeded depending on the environmental conditions or/and the stability of the transducer to be calibrated. It is the responsibility of the laboratory or end user to make sure that the reported values of expanded uncertainty are credible.

Table 7 — Attainable uncertainties

Site	Parameter	Example 1	Example 2
Vibration calibration laboratory	Sensitivity (0,1 Hz~100 Hz)	1 %	2 %
	Electric sensitivity (0,1 Hz~100 Hz)	1 %	1,5 %
	Coefficient of calibration coil (0,1 Hz~100 Hz)	2 %	3 %
In situ	Electric sensitivity (0,1 Hz~100 Hz)	1,5 %	4 %
	Sensitivity (0,1 Hz~100Hz)	5 %	10 %
NOTE The expanded uncertainties given as examples are based on specific uncertainty budgets; see Annex B.			

6 Report of calibration results

When the calibration results are reported in laboratory, in addition to the calibration method and instrumentation with calibration due dates, at least the following conditions and characteristics shall be stated.

a) Ambient conditions:

1) temperature of the transducer;

2) level of the environmental vibration.

b) Mounting technique:

1) material of mounting surface;

2) characteristics of mounting components or adapters (if used);

3) oil or grease or wax (if used);

4) cable fixing;

5) orientation (vertical or horizontal).

c) All amplifier settings (if adjustable) when the transducer is calibrated in combination with a signal conditioner or amplifier:

1) gain;

2) cut-off frequencies and slope of filters.

d) Calibration results:

1) values of calibration frequencies and vibration amplitudes;

2) values of sensitivity;

3) values of electrical sensitivity;

4) values of coefficient of calibration coil;

5) expanded uncertainty of measurement, k factor if different from k = 2.